

Centenary of Philip Henry Gosse, F.R.S.

Born April 6, 1810; died Aug. 23, 1888.

The Secretary exhibited the set of the works of Philip Henry Gosse in the Society's Library and gave a brief summary of his contributions to science, upon which he placed a very high value. The Chairman and Prof. A. Sedgwick, F.R.S., added their testimony to his place in Zoological history; Dr. Henry Woodward, F.R.S., gave some personal reminiscences; and Mr. Edmund Gosse, Librarian of the House of Lords, the son and biographer of Gosse, thanked the Society for their notice of his father's centenary.

The following papers were read:—

1. Notes on the Photophores of Decapod Crustacea.

By STANLEY KEMP, B.A.*

[Received March 1, 1910.]

(Plates LII.–LIV.†)

Two different methods of producing light are known among Crustacea. In the vast majority of species possessing this power the organ is of a glandular nature, excreting drops of oily fluid which become luminous on reaching the water. The process is probably one of oxidation, though from the results of Giesbrecht's experiments‡ it would seem that very small quantities of free oxygen will suffice.

Certain Decapods, such as *Polycheles phosphorus*, appear to produce light in this way, while in others, such as *Aristeus coruscans* and *Heterocarpus alphonsi*, the excretions from the antennal glands have been noticed to be brilliantly phosphorescent§. Both these phenomena seem to be exceedingly rare among Decapods.

The second method of producing light, and it is only with this type that the present paper is concerned, is by means of photophores, compound luminous organs which do not excrete a fluid; they are in most cases provided with a lens and sometimes also with a reflector. Very little is known of the chemical processes which are involved in this type of phosphorescence. The essential feature, as in the case of the glandular organs, is doubtless one of oxidation, and it is probable, as Alcock has suggested, that the oxygen is conveyed to the photophore by means of the blood.

Among Crustacea, photophores are known only in the Euphausiacea and in the Decapoda. In the former group they are very highly specialised and occur in practically all the species known.

* Communicated by Dr. W. T. CALMAN, F.Z.S.

† For explanation of the Plates see p. 650.

‡ Giesbrecht, Mitth. Zool.-Stat. Neapel, ii. 1895, p. 648.

§ See Alcock, 'A Naturalist in Indian Seas,' 1902, pp. 134 & 135.

Their true function was first demonstrated by Sars *, and their structure is now well known owing to the work of Chun † and of Vallentin and Cunningham ‡.

Photophores occur only in three genera of Decapoda, all of which belong to the Macrura, or, according to modern systems of classification, to the Natantia. One of them, *Sergestes*, belongs to the Penæidea, and the other two, *Acantheephyra* and *Hoplophorus*, to the Caridea. Although, as might be expected, two wholly different types of structure are found in these two groups, they have none the less one very striking feature in common—in both a deep blue pigment is associated with the luminous organ. This pigmentation is one of the most interesting characteristics of the photophores of Decapoda, for, except for the fact that it has once been observed in a Euphausian, such an association appears to be elsewhere unknown.

The following six species of Decapods possess photophores:—

PENÆIDEA.

Sergestidae..... *Sergestes challenger* Hansen.
Sergestes gloriosus Stebbing.

CARIDEA.

Hoplophoridae ... *Acantheephyra pellucida* Perrier.
Acantheephyra debilis A. Milne-Edwards.
Hoplophorus grimaldii Coutière.
Hoplophorus sp. juv.

Two other genera, *Gennadas* and *Amalopenæus*, belonging to the family Penæidae, may also possess photophores, but it has not as yet been possible to come to any definite conclusion on the subject.

The material which I have been able to examine consists of one species of each of the three genera mentioned above. I am indebted to Prof. J. Stanley Gardiner for the opportunity of examining four specimens of *Sergestes challenger* and an immature *Hoplophorus* from the Indian Ocean. The examples of the former genus are preserved in formalin and have in consequence retained some at least of their original pigmentation. *Acantheephyra debilis* occurs in all stages off the West coast of Ireland. This species is unfortunately far from common, and although special efforts have been made, no fresh material has been found during the last eighteen months. In consequence, it has not been possible to solve certain problems connected with the pigmentation and innervation of the photophores.

Deep-sea Decapods are almost invariably dead when brought to the surface, and although in view of recent investigations it does not seem probable that the vitality of the organism has

* Sars, Report on the 'Challenger' Schizopoda, 1885, p. 70.

† Chun, Bibliotheca Zoologica, Bd. vii. (Heft 19), 1896, p. 191.

‡ Vallentin & Cunningham, Q. J. Micr. Sci. xxviii. 1888, p. 319.

any direct effect on the production of light, it is none the less the case that phosphorescence has actually been observed only in a single species, *Sergestes challenger*i. Prof. Gardiner informs me that the examples of this form which he obtained in the Indian Ocean were brilliantly phosphorescent on the occasion of their capture. In the other species the function of the organs has been deduced from their structure only.

THE PHOTOPHORES OF *SERGESTES*.

The only two species of *Sergestes* which are known to possess photophores are *S. challenger*i, which was described by Hansen* from a single specimen obtained by the 'Challenger' Expedition near the Fiji Islands, and a closely allied form, *S. gloriosus* Stebbing†, which was found in South African waters. Hansen discovered 117 photophores in his mutilated example of *S. challenger*i, and estimated that at least 150 would be found in a perfect specimen. According to Stebbing's account an even greater number exist in *S. gloriosus*.

It is not necessary to describe the distribution of the photophores in detail. They occur on the lower sides of the eyestalks, antennules and antennal scales, on the oral appendages, on the thoracic and abdominal sterna, on the ventral surface of the outer uropods, and on many of the leg joints. All are so situated that the light which they produce is thrown directly or obliquely downwards. In both the species photophores have been described on the lateral face of the carapace. These, however, at any rate in *S. challenger*i, are not external, but are placed in the roof of the branchial chamber and illuminate the gills from above (Pl. LIV. fig. 4). To find photophores in such a position as this is most astonishing, and it is not easy to suggest any theory which will account for their curious situation.

The photophores are all practically identical in structure and all are quite immovable, though a few are supported on very short, thick stalks in order to make them bear more directly downwards. They vary considerably in size, but even the largest are much smaller than the organs on the pleopods of *Acanthephyra debilis*. In a single individual the diameter of the lens was found to range from .06 to .14 mm.

The structure of the organs is illustrated in Pl. LIII. figs. 2-4 and in Pl. LIV. figs. 2, 3, & 5.

Externally there is a double convex lens. This is made up of two distinct portions, which are formed from the two layers composing the cuticle. The outer part is double convex, while the inner, which is closely applied to it, is concavo-convex. In sections treated with picro-carmin the inner lens often stains to a rather deeper red tone than the outer, but the complete absence of any yellow colour indicates that the cuticle of which both are formed

* Hansen, P. Z. S. 1903, p. 72.

† Stebbing, Marine Invest. in S. Africa, vol. iv. 1905, p. 84.

is not more strongly chitinised than the rest of the exoskeleton. Both portions are quite transparent in material preserved in weak formalin. A very delicate investing membrane possibly occurs on the outer side of the lens, but its presence could not be demonstrated clearly in any of the sections obtained.

Situated immediately behind the lens and exceeding it in diameter is the first cellular layer. This is composed of a number of large wedge shaped cells which appear to be derived from the epithelium; from eight to ten are seen in a median section of the organ. They are all full of protoplasm and their nuclei invariably lie close up against the lens. In material preserved in formalin this layer is seen to be impregnated with a deep blue pigment.

The second cellular layer is extremely inconspicuous; it consists merely of a few flattened nuclei round the outside of the first layer.

The third layer Hansen very reasonably considers to be a reflector. In material preserved in formalin it is of a distinctly yellow colour; it is faintly striated and contains numerous pear-shaped nuclei which are very regularly arranged with their narrow apices directed towards the lens.

The fourth and last layer consists of a number of irregularly disposed cells round the back of the reflector. It is possible that in life these carried a pigment, but in the preserved specimens no trace of this remains.

In some instances a nerve-strand communicating with the photophore was detected, but the exact mode of its entrance could not be discovered. It is not improbable that it runs round the edges of the reflector and then turns inwards to supply the first cellular layer, in much the same way as has been demonstrated by Chun in the photophores of Euphausians.

One of the two organs placed on the underside of the eyestalk is situated in closest proximity to the cornea. In this case (Pl. LIV. fig. 2) the photophore is slightly twisted and is directed forwards and downwards. It is shut off from the cornea by a layer of black pigment, and its nerve-supply is not drawn from any of the optic ganglia, but from a separate strand which runs up the inferior margin of the stalk.

It will be noticed from Pl. LIII. figs. 2, 3, that the lens may differ considerably in convexity, and in one case (fig. 4) it is plano-convex. This photophore is placed at the base of the exopod of the first maxillipede and is directed forwards; as Hansen mentions, it is partially, though not entirely, overhung by the surrounding tissues.

In neither of the two species is anything known of the development. The photophores, however, differ slightly in number in the examples which I have examined, and it is probable that, as in the case of *Acanthephyra debilis*, they continue to increase as the specimen gains in size. Additional organs seem to appear long after the individual has attained maturity.

A comparison of the foregoing description with the account and figures which Hansen gives of the structure of these organs reveals many discrepancies. There can be little doubt that this is due to the fact that Hansen viewed the organs only in optical section, a method which, even in his hands, has not yielded satisfactory results.

THE PHOTOPHORES OF *ACANTHEPHYRA*.

Two species of *Acanthephyra* are known to possess photophores. They are first mentioned by Perrier in 1886* in a form which he called "*Acanthephyra pellucida* A. Milne-Edwards." There is unfortunately a good deal of uncertainty regarding the validity of this species, for it has not been rediscovered in recent years and Milne-Edwards seems to have never published any description. Our knowledge of it is, in consequence, derived solely from the brief reference in Perrier's work, and the accuracy of the account of the distribution of the photophores, which is there given, is by no means certain †.

Acanthephyra debilis is better known. Coutière in 1905‡ described the existence of photophores in this species, and in 1906§ he published a more complete account of their number and distribution.

The photophores in *A. debilis* are not all of similar structure, as they are in the case of *Sergestes*, but exist in different degrees of complexity in different parts of the animal.

The most highly developed organs are twelve in number, and each is so placed that the light which it produces is thrown directly downwards. One is situated on the distal and external aspect of the protopodite of each pleopod, and one behind the protopodite of each uropod. The structure of these photophores is illustrated in Pl. LII. fig. 1 and Pl. LIV. fig. 1.

Externally there is a thick concavo-convex || lens formed from the cuticle. In adult specimens this measures about .24 mm. in diameter, and during life is of a deep violet-blue colour. The pigment does not exist as a mere coating, but permeates throughout the structure of the lens. Sections stained with picrocarmine show that the lens is made up of three distinct layers. The inner and outer portions are merely thickenings of the two cuticular layers which form the normal exoskeleton of Crustacea and under a high power show the usual striations. The middle layer, which is also striated, always stains more deeply with carmine than the others, and, owing to the fact that it sometimes takes

* Perrier, Les explorations sous-marines, 1886.

† A comparative view of the positions occupied by the photophores in *A. pellucida* and in *A. debilis* will be found in Kemp, Fisheries, Ireland, Sci. Invest., 1908, I. [1910], p. 67, where Perrier's original description is reprinted.

‡ Coutière, Bull. Mus. Océanog. Monaco, no. 48, 1905, p. 7.

§ Coutière, Bull. Mus. Océanog. Monaco, no. 70, 1906, p. 4.

|| In a few of the sections obtained the lens is plano-convex, but this I believe to be due to distortion.

up a certain amount of yellow colour (due to the picric acid in the stain), it seems probable that it is formed of a more strongly chitinated material. The cuticle is thrown in folds on either side of the lens. It is possible that by this structure a limited amount of movement is permitted to the photophore, but no trace of a controlling muscular apparatus could be found.

Inside the lens there is a series of very large elongate cells which radiate from a well-defined centre to its inner surface. They measure from .08 to .10 mm. in length; twenty are usually visible in a median longitudinal section, consequently at least three hundred must occur in the whole organ. The proximal portions of these cells appear to be wholly devoid of protoplasmal contents. The nuclei* are very regular in shape and, as in the first cellular layer of *Sergestes*, lie close up against the lens. The outer end of each is evenly rounded, and a band of cytoplasm may sometimes be seen between it and the lens; the inner end is squarely truncate. The nuclei differ curiously in size, for in all the sections obtained the length is proportional to the distance from the centre of the lens. This results, in effect, in the formation of an additional lens, concavo-convex and built entirely of nuclei, which is placed immediately behind that formed from the cuticular layer. There can be little doubt that such a provision as this must have a marked effect on the optical qualities of the apparatus.

The central part of the organ is occupied by a number of minute highly refractive granules which are massed together in a conical shape round the extremity of the nerve-bundle. These granules are quite colourless in every section obtained; carmine, picric acid, and hæmatoxylin are all equally ineffectual in staining them. The nerve-strand leads straight down the pleopod to the photophore, and, as may be seen from the figures, it expands into a number of ramifying filaments before it converges to the granular cone.

Numerous cells with large nuclei are irregularly disposed round the inside of the photophore. It is possible that these were pigmented when the animal was living, and served as a screen to prevent light penetrating inwards, but no confirmation of this was obtained.

In a freshly caught specimen of *Acanthephyra debilis* a dark violet-blue streak is easily seen on each side of the inner wall of the carapace immediately behind the last pair of thoracic legs. From the structure which these organs possess it is evident that they also are photophores, although they are much less highly specialised than those at the base of the pleopods.

In a transverse section (Pl. LII. fig. 2) the lens, which is dark blue in fresh material, is seen to be merely a slight thickening of the cuticle, and the densely staining central layer is entirely absent. The epithelial cells are greatly elongated, as in the

* There can be no doubt that these bodies are nuclei, for by the use of hæmatoxylin chromosomes were demonstrated in them.

photophores on the pleopods, but their arrangement is not so regular, and though the majority of the nuclei are placed near the lens this is by no means the case with all. The cells show a tendency to converge towards a point, but no granules similar to those in the other photophores were detected. In some sections a nerve-strand may be seen leading away from the organ and passing between two muscle-bands.

Other spots and streaks of dark blue pigment to the number of 133 are found in adult examples of *A. debilis*. They occur on the eyestalks, on certain legs, on the branchiostegites and other parts of the carapace, on the abdominal segments and on the telson. With the exception of a small number, which occur on the dorsal aspect of the carapace, abdomen and telson, all are situated laterally or ventrally.

Contière, while fully realizing that little or no structural evidence could be advanced in favour of such a theory, has no hesitation in ascribing a luminous function to the cells underlying these pigment-spots. With this view I fully concur, and, as will be seen later on, I am able to bring forward another fact which supports this interpretation.

In the only passage in which he remarks on the anatomical characters of the organs, Contière * says: "Les organes lumineux de la base des pléopodes paraissent se rapprocher beaucoup de ceux des Euphausiidae, tous les autres semblent être de simples amas de cellules à lumière, disposées sur une seule assise et recouvertes de pigment." With the latter part of this sentence I am in entire agreement. In numerous sections, made through all the more prominent spots of pigment, the underlying cellular layer presents no visible difference from that of the adjacent tissue. To this there is only one exception: a section cut transversely through the telson near the apex (Pl. LIII. fig. 1) shows that the cells beneath the dorsal spot of pigment are greatly elongated, though their nuclei differ in position from those found in the more elaborate organs.

The brilliant scarlet-red pigment, which is such a notable characteristic of many deep-sea Decapods, presents features of special interest in the case of *Acantheephyra debilis*, for it is quite undeveloped in the neighbourhood of the luminous organs. This is particularly well shown in the case of the photophores at the base of the pleopods. Viewed laterally, these organs would be quite invisible, being wholly covered by the flaps formed by the abdominal pleura, were it not that in these parts the red pigment is entirely absent, leaving the transparent cuticle through which the light emitted by the photophore may shine as through a window. The luminous streaks behind the last pair of thoracic legs are covered by the branchiostegal wall of the carapace, and in these a precisely similar phenomenon may be observed.

Red pigment is also absent from the vicinity of all the numerous

* *Loc. cit.* 1906, p. 4, footnote.

organs which, when sectioned, show no definite structure. In a freshly caught specimen each appears as a deep blue spot circumscribed by a belt of colourless tissue. Such a distribution of pigment seems to afford considerable support to the view, advanced by Contière, that all the blue spots represent luminous organs.

An examination of young specimens of *A. debilis* shows that, as might have been expected, the complex organs are those which appear first. The eggs are very large and consequently the young are liberated in a rather advanced stage. The earliest-known larva possesses twelve luminous organs, viz., those on the pleopods and behind the fifth pair of legs. A little later the other compound photophores behind the protopodites of the uropods appear and simultaneously with them certain of the simple organs. At every succeeding moult fresh spots of blue pigment appear, until in the largest individual known they have reached the total of one hundred and forty-seven*.

THE PHOTOPHORES OF *HOPLOPHORUS*.

Contière (*loc. cit.* 1905, p. 1) first described these organs in a species which he named *Hoplophorus grimaldii*. Thanks to the kindness of Prof. Gardiner, I have been able to examine an example of this genus from the Indian Ocean. The specimen is unfortunately immature, but, as might have been expected, the photophores were not found to differ in any essential feature from those occurring in the closely related form *Acantheephyra debilis*. Although the simpler organs are by no means so numerous as in that species, all those of a more complex character are present and occur in the usual positions on the pleopods and uropods, and behind the base of the last pair of legs.

Contière mentions that in his specimen of *Hoplophorus*, "conservé dans la glycérine formolée," the luminous organs are slightly yellowish; in the example from the Indian Ocean, which was preserved in spirit, no trace of pigment remains. The photophores are, however, so completely identical in structure with those occurring in *Acantheephyra*, that, notwithstanding the fact that the blue coloration has never been seen in *Hoplophorus*, there can be little doubt that such a pigment really exists in living specimens.

Whether the organs occur in all the species or whether, as in the case of *Sergestes* and *Acantheephyra*, they exist only in a limited number, must be left to future investigators.

THE PIGMENTATION OF THE PHOTOPHORES.

It has already been mentioned that a deep blue pigment is, in life, associated with the photophores of Decapoda, occurring in

* For the order in which these organs arise and their number in specimens of different age, v. Contière, *loc. cit.* 1906, and Kemp, Fisheries, Ireland, Sci. Invest., 1908, I. [1910].

Sergestes in the first cellular layer and in *Acantheephyra* in the lens itself.

There is reason to believe that this pigment is closely allied to, if not identical with, that found in the Lobster. When the photophore is placed in absolute alcohol the blue colour soon becomes bright red, and the same reaction instantaneously appears when it is boiled in a drop of water. If the lens of *Acantheephyra* be dissected out and treated with strong sulphuric or nitric acid the colour at once changes to red, and immediately afterwards turns to a dull greenish blue of a much less distinct colour than that originally present. The greenish-blue tone appears to fade away a little later, but the concluding stages of the reaction are somewhat obscured owing to the burning of the tissue by the acid.

The red pigment which gives the familiar colouring to *Nephrops* and to the lobster, when boiled, is known to be one of the lipochromes or fatty pigments, called by Moseley *crustaceorubin*, associated with a small quantity of yellow pigment, known as *hepatochrome*, which appears to be derived from the liver. The investigations of Krukenberg* and of Miss Newbigin† seem to show that the unstable blue-black pigment or *lipochromogen* which occurs in the lobster is a compound of the red lipochrome with a complex organic base. The blue colour is turned red by any reagent which alters the form of the proteid, and the red pigment, extracted and dried, gives with strong acids a brilliant but evanescent blue reaction.

The photophores are unfortunately so minute that it is not possible to extract a solution of the pigment; but the reaction mentioned above, which was obtained by the addition of acid to the lens of *Acantheephyra*, furnishes fairly satisfactory evidence of the nature of the pigment‡. The acid breaks up the proteid and at once converts the blue *lipochromogen* into the red lipochrome, and this is immediately followed by the characteristic blue reaction which this pigment gives in the presence of an acid. The tissues burn and become brown under the influence of the reagent, and the rapid evanescence of the blue tint, which is characteristic in the case of dry extracted pigment, is in consequence somewhat masked.

It has not been possible to test the blue pigment in the photophores of *Sergestes* as fully as has been done in the case of

* Krukenberg, Vergleich. Physiol. Studien, IIte Reihe, 3te Abteil., 1882, pp. 92-107.

† Newbigin, 'Journal of Physiology,' vol. xxi. 1897, p. 237.

‡ The following observations on the red colouring-matter of *Acantheephyra* may be mentioned here. An ether extract of the pigment gave a bright yellow solution, which on evaporation yielded an oily red extract. On the addition of strong nitric acid a bright, but rapidly evanescent, blue reaction was obtained which was followed by the separation of the red matter from the oily yellow pigment, the latter turning a dull green. This result is practically identical with that obtained by Miss Newbigin with the extracted pigments of *Nephrops*. The red colouring which turns blue under the influence of the acid is the lipochrome, *crustaceorubin*, while the oily yellow pigment is *hepatochrome*.

Acanthephyra, but from the fact that it turns red when boiled or when treated with strong acids it is very probable that it is of the same nature.

The existence of blue coloration in deep-sea animals is exceedingly rare, and its occurrence among Decapoda in close association with the photophores is almost unique, for among the Euphausiacea a similar pigment appears to have been noticed only on a single occasion. In November, 1909, a large specimen of *Thysanopoda acutifrons* Holt & Tattersall was caught in a mid-water net off the West coast of Ireland. This specimen, which was dead by the time it reached the deck, was found to possess patches of deep blue pigment associated with the photophores on the eyestalks. Casual examination failed to reveal this pigment in the other photophores, which, however, were of a darker colour than is usually the case. The specimen was put aside in a dish of water and when it was again examined, not more than half an hour later, all trace of the blue pigment had vanished. It is evident that, even if in this case the blue colouring invariably occurs in the photophores, the phenomenon is one of great rarity among Euphausians, for it certainly is not found in *Meganyctiphanes norvegica* or in any of the common N. Atlantic species.

The blue pigment of the photophores of Decapoda is much more stable than that noticed in *T. acutifrons*. Although rapidly extracted by alcohol, it will persist for years in specimens preserved in weak formalin, remaining distinct long after the general red colouring has disappeared.

The lens of *Acanthephyra*, being blue, can necessarily only allow the emission of blue light and it is not impossible that this is also true in the case of *Sergestes*, where the lens is transparent and the first cellular layer blue. It seems then that, at least in the former genus, the production of blue light is a necessity, but it is impossible to suggest any explanation of this curious phenomenon.

Photophores have evidently been developed by Crustacea in at least three separate instances. Those possessed by *Acanthephyra* and *Hoplophorus* are in structure wholly distinct from those of *Sergestes*, while in neither case is there any resemblance to the very complex organs of the Euphausiacea.

It is a remarkable fact that, whereas in the latter order the possession of photophores is the general rule (only in *Bentheuphausia* are they absent), their occurrence in large genera such as *Sergestes* and *Acanthephyra* is limited to a few species only. This is particularly noteworthy in *Sergestes*, in which two forms, both of which are classed among a small group of extremely closely allied species, exhibit a large number of photophores, whereas none are to be found in the other members composing the group.

Doflein, in a short but interesting paper *, has summarised the

* Doflein, Sitzungsber. d. Ges. f. Morphol. und Physiol. in München, xvii. 1907, pp. 133-136.

various suggestions which have been made as to the use of luminous organs to marine animals. He remarks that they probably serve different functions in different groups of animals and classes them in four sections.

i. Attraction of prey (chiefly important in sessile or slowly moving animals).

ii. Attraction of other individuals of the same species, either (a) for the formation and maintenance of swarms or (b) to enable the sexes to find and recognise one another. In this connection Doflein points out that animals with a complicated system of photophores always possess highly developed eyes, and refers to Brauer's theory that the varying arrangement of photophores produces light patterns serving as recognition marks, like the colour-patterns of animals living in daylight.

iii. Protection. The clouds of luminous secretion emitted by some species may possibly serve the same purpose as the ink of the cuttlefish, and photophores may also by a sudden flash of light scare a pursuer. In the fauna of land and shallow water a brilliant colouring is often assumed as a signal that the species is distasteful, and some deep-sea animals may, for the same purpose, exhibit warning lights.

iv. Illumination of objects viewed by the animal. On this theory it is difficult to account for the ventral and lateral position of the photophores in many marine animals*. In Crustacea this is particularly well shown, for the large majority of the organs illuminate regions which seem altogether out of range of the eyesight.

It is evident that these suggestions will not account for every case which can be found; the photophores in the roof of the branchial chamber of *Sergestes* remain inexplicable.

The vast majority of marine animals which possess photophores live at the surface or at intermediate depths and never occur on the bottom. No exceptions to this rule have been noticed in the deep-water fauna of the Irish Atlantic slope, but it seems that the two Euphausiids, *Meganycetiphanes norvegica* and *Nyctiphanes couchii*, are sometimes found on the bottom in shallow water. On one or two occasions large numbers of these two species have been caught off the Irish coast at depths of 40 to 60 fathoms, and there are indications that the specimens which were obtained in these hauls were actually living on the sea-floor. The same two species are frequently obtained over depths of 400–800 fathoms off the West coast of Ireland, and here they invariably occur in midwater.

It must be remembered that the ordinary open-mouthed nets, which are generally employed for bottom work, frequently catch

* Miss Massey informs me that when studying the development of the Cephalopod, *Histioteuthis bonelliana*, which when adult possesses photophores all round its body, she noticed that the organs are developed first on the side which is ventral when the animal is swimming.

midwater organisms while being hauled, and there is reason to believe that errors arising from this source exist in many of the instances in which animals bearing photophores have been recorded from the bottom.

Many of the higher marine animals live on the sea-floor at depths to which no ray of sunlight can ever penetrate, and, though they possess well-developed eyes, are themselves, for the most part, without any special illuminating apparatus. That light exists at these depths seems almost certain. It is probably fairly plentiful in regions thickly populated by Cœlenterates, and the excretions of numerous animals of a more highly organised nature have been found to be brilliantly phosphorescent. The restriction of photophores to species living in midwater seems only explicable on the theory that there is a comparatively plentiful supply of light on the bottom itself.

The sections of the photophores were made by the paraffin method in the laboratories of Trinity College, Dublin. Decalcification was not attempted, for it was found that the cuticle was sufficiently soft without it, this, perhaps, being due to the fact that the specimens were preserved in formalin.

In conclusion, I wish to acknowledge my indebtedness to Dr. W. T. Calman for much useful help and criticism, and to Dr. H. H. Dixon for his valuable assistance and advice in the preparation of the sections and micro photographs.

EXPLANATION OF THE PLATES.

PLATE LII.

The figures on this Plate are reproduced from micro-photographs.

Acanthephyra debilis A. M.-Edw.

Fig. 1. A longitudinal section of a photophore from the protopodite of the pleopod. $\times 185$. (Compare fig. 1, Pl. LIV.)

2. A transverse section of the photophore behind the base of the last pair of legs. $\times 133$.

PLATE LIII.

The figures on this Plate are reproduced from micro-photographs.

Acanthephyra debilis A. M.-Edw.

Fig. 1. A transverse section of the telson near the apex, passing through the median dorsal patch of blue pigment. The section shows the regular arrangement of nuclei below this area and also the bases of two spines cut transversely. $\times 93$.

Sergestes challengerii Hansen.

Fig. 2. A median photophore from the thoracic sternum, cut transversely. $\times 320$.

3. Part of the penultimate joint of the second maxillipede, cut longitudinally, showing a photophore in transverse section. $\times 247$. (Compare fig. 3, Pl. LIV.)

4. The photophore at the base of the exopod of the first maxillipede in transverse section. $\times 300$.

PLATE LIV.

The figures on this Plate are semi-diagrammatic.

Acanthephyra debilis A. M.-Edw.

- Fig. 1. A longitudinal section of a photophore from the propodite of a pleopod. The cellular layer (*c.*), which is apparently derived from the epithelium, is composed of long cells with densely staining nuclei at their outer ends. The only cytoplasm which is visible lies between the nuclei and the inner face of the lens. $\times 210$. (Compare fig. 1, Pl. LIII.)

Sergestes challenger Hansen.

- Fig. 2. A longitudinal section of the eye-stalk showing the photophore (*ph.*) lying close to the eye (*e.*) and separated from it by a curtain of black pigment (*p.*). $\times 160$.
3. A photophore from the penultimate joint of the second maxillipede in transverse section. $\times 380$. (Compare fig. 3, Pl. LIII.)
4. A transverse section of the branchial chamber showing an arthrobranch (*a.*) and one of the four photophores (*ph.*) which are set in the roof of the cavity and appear to illuminate the gills from above. $\times 44$.
5. The same photophore on a larger scale. The two layers of the lens (*i.l.* and *o.l.*) and the first cellular layer (*c.*) are formed from the cuticular and epithelial layers of the inner surface of the branchiostegite. $\times 380$.

Reference letters :—

- a.* Arthrobranch.
b. Branchiostegite.
c. Cellular layer (in *Acanthephyra*).
c'. First cellular layer (in *Sergestes*).
c''. Second cellular layer (in *Sergestes*).
e. Eye.
e.l. Epithelial cell-layer.
g. Cone of minute highly refractive granules in close connection with nerve-strand.
i.c. Inner cuticular layer of branchiostegite.

- i.l.* Inner layer of lens.
m.l. Middle layer of lens.
n. Nerve.
o. Optic ganglia.
o.c. Outer cuticular layer of branchiostegite.
o.l. Outer layer of lens.
p. Curtain of black pigment between photophore and eye.
ph. Photophore.
r. Reflector or striated layer.
s.l. Sheathing layer of cells.

2. On the Varieties of *Mus rattus* in Egypt; with General Notes on the Species having reference to Variation and Heredity. By J. LEWIS BONHOTE, M.A., F.L.S., F.Z.S.

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(Text-figures 58-62.)

While spending a few months recently at the Giza Zoological Gardens, near Cairo, I was enabled through the kindness of the Director, Capt. S. S. Flower, to examine a large number of the common House Rats of the district. I gladly took advantage of the opportunities thus offered, as I was convinced that a close study of this species would throw some light both on the causes of variation and on the inheritance of the varieties that are found in such profusion in *Mus rattus*.

In addition to the rats which were caught in the Gardens, Dr. Charles Todd, of the Public Health Department, kindly allowed me to examine and measure all the rats that came into his hands during the time that I was in Cairo. These rats were taken in various towns and villages in the Delta by special catchers employed by the Public Health Department, the result being that